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Gateroad Development - The Correct Method, the Correct Equipment?

N Gow¹

INTRODUCTION

Longwall mining in Australia is approaching maturity. Longwall production from 'state of the art' Australian longwall mines now rivals similar US based longwall operations. Regrettably however, Australian gate road development rates in general fall short of the required development to longwall production ratios that are required to sustain annual longwall production capabilities. By contrast, most US based longwall mines achieve the required development to longwall production ratios to sustain their longwalls. This is despite many having to drive three heading longwall panel gate headings to meet regulatory requirements.

In Australia the focus in recent years has been on the improvement of roadway support capabilities of continuous miners. The goal has been to integrate coal cutting and loading with roadway support. Notable products resulting from this focus have been the Joy 12CM 30, Jeffrey 2048 and more recently the Voest Alpine ABM20. Other innovations in this arena have been designed and some have been trialed as prototypes. These machines have included the Joy Sump Shearer and Long-Airdox KB2 miner. Despite these improvements, development rates generally still lag behind those needed to meet improved longwall capabilities.

The US coal industry, on the other hand, has generally focused on using existing high capacity continuous miners in place - changing gate road panels together with purpose built high capacity roadway support machines. This system has generally provided adequate development to longwall production ratios in US mines.

As more Australian mines seek improved development to longwall production ratios, some operators have opted to introduce place-changing methods into gate road development. Many operators are considering this option whilst other operators seek to improve an existing more conventional gate road development system.

This paper attempts to demonstrate, through modelling of non-identified actual mine scenarios, the opportunities and options available to mine operators when considering a choice between place-changing methods as compared to continuing with integrated mining and roadway support methods.

As mentioned above, considerable development has occurred in integrating roadway support into the routine operation of the continuous miner. In parallel with this, continuing development of higher capacity continuous miners, suitable for place-changing, has proceeded in the US and these have been made available in Australia.

Up until recently, far less attention had been given to improving coal clearance from the back of continuous miners. The shuttle car was the principal method of carrying continuously mined coal and still largely remains the most popular, despite its aging technology (approaching 30 years) and ongoing inadequacies.

Over the intervening years, several attempts have been made to supersede the need for shuttle car coal clearance. Some operators have experimented with the introduction of "mobile boot end" technology to eliminate the need for shuttle cars, but with only limited success.

Earlier attempts to introduce continuous haulage into Australian coal mines failed because of deficiencies in equipment design and conveyor belting durability, the concept being subsequently abandoned. A bridge conveyor type continuous haulage system has recently been reintroduced into the Australian coal industry. The industry awaits with considerable interest the outcome of its introduction.

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The recent introduction of battery coal haulers into gate road development has shown promising results. This technology, although relatively new to the Australian coal industry, is well proven in the US, having been used since 1984.

The second part of this paper focuses on coal clearance alternatives for gate road development. The author, from his personal experiences expresses a view as to the relative merits of each alternative, and productivity predictions from recent modelling of non-identified actual mine scenarios.

THE CORRECT METHOD

At the outset it needs to be said that there is no categorically correct method. The choice between the place-changing method and the integrated mining and roadway support method primarily depends upon two major factors.

1. The Depth of Cut

This is normally determined by geotechnical considerations, particularly as the completed excavation must conform to a specification that supports longwall extraction. Cut depths in Australia range from a maximum of 15 m down to 2 m.

For the purpose of the supporting modelling, cut depths were set at 6 and 10 metres respectively

2. The Pillar Dimensions

Pillar dimensions have a direct effect on-

- a) The percentage of delay directly attributable to changing out haulage units.
- b) The percentage of delay directly attributable to flitting the continuous miner to the next working place

Model outcomes

For the purpose of supporting modelling, pillar dimensions were set ranging from 60 m x 30/40 m to 204/250 m x 30/40 m respectively.

As shown in Figs. 1 and 2, the model clearly demonstrates that the place-changing system offers superior productivity outcomes, compared to the integrated mining and roadway support system, for battery haulers up to pillar lengths of 150 m. The result for pillar lengths over 150 m was that the integrated mining and roadway support system offers a superior productivity outcome as compared to the place-changing system.

Shuttle cars were not modelled beyond 150 m as pillar lengths over 150 m generally cannot be serviced by shuttle cars without the requirement of surging. Surging normally results in less than satisfactory outcomes for many varied reasons.

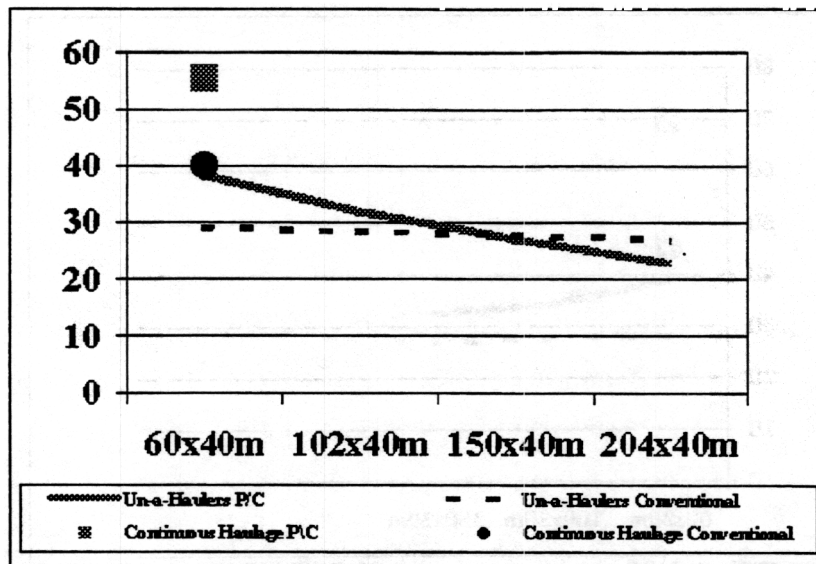


Fig. 1-Un-a-Hauler productivity analysis (with 6m cut)

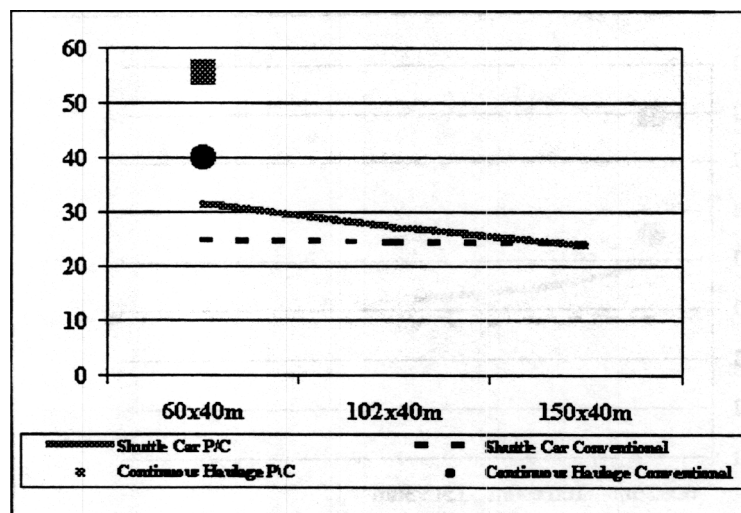


Fig. 2 - Shuttle car productivity analysis (with 6m cut)

As shown in Figs. 3 and 4, the opportunity to access a 10 m cut-out further improved the place-changing system's advantage over the integrated mining and roadway support system.

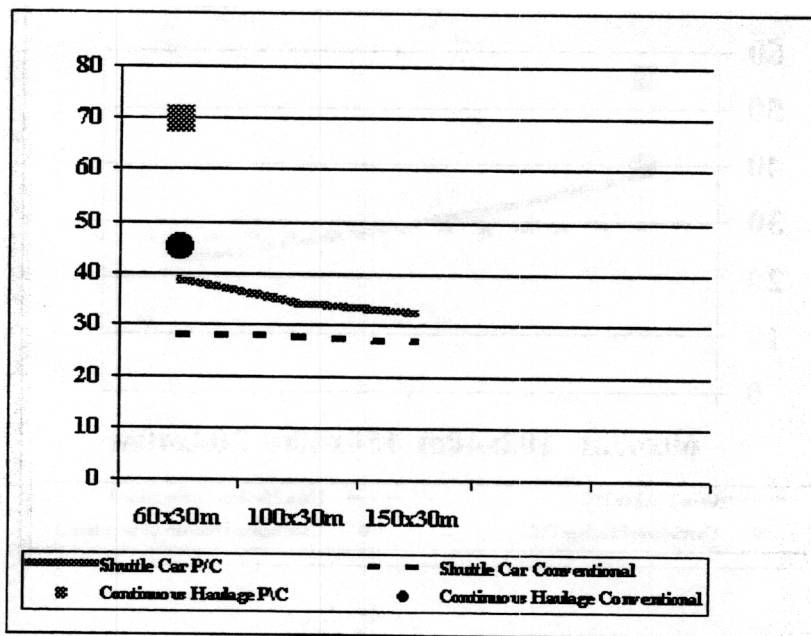


Fig. 3 - Un-a-Hauler productivity analysis with 10m cut

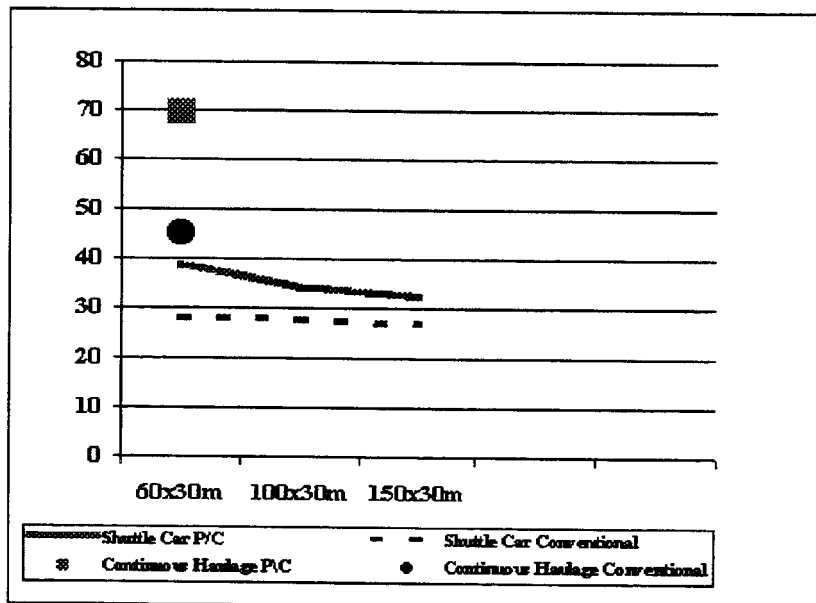


Fig. 4 - Shuttle car productivity analysis with a 10m cut

The use of battery haulers allowed access to the place-changing system's superior development productivity as compared to the integrated mining and roadway support system in pillar lengths of up to 200m. Pillar lengths over 200m resulted in the integrated mining and roadway support system being more productive than the place-changing system.

The use of shuttle cars provided productivity superiority in the place-changing system as compared to the integrated mining and roadway support system for all pillar lengths up to 150m, the limit of reach for shuttle cars without surging.

Comment

Detailed modelling suggests that operators can improve gate road development rates in mines through the introduction of the place-changing system of roadway development.

Pillar lengths of up to 150m can be more efficiently driven using the place-changing system, with a 6m cut, and shuttle car coal haulage.

The introduction of battery haulers will allow more efficient drivage of up to 150m length pillars and even longer pillars, of up to 200m length, using the place-changing system and extending the cut to 10m.

THE CORRECT EQUIPMENT

Equipment selection is an arduous and time consuming task. The capital cost of development equipment is considerable and many operators have suffered the disappointment of less than satisfactory results from the introduction of new technology.

The following section looks at the various coal haulage alternatives available to complement existing improvements available in current continuous miner variants.

The general options available in coal haulage equipment are-

1. Shuttle cars,
2. Mobile boot end,
3. Battery haulers, and
4. Continuous haulage

Shuttle cars

Shuttle cars as shown in Fig. 5, have provided the mainstay of coal haulage from continuous miners for approximately 30 years. Their payload capacity ranges from 7 tonnes to 12.5 tonnes.

The use of shuttle cars in gate road development is well understood by coal mine operators and therefore requires no further explanation.

The major advantage of shuttle cars and therefore their continued use stems from the longtime knowledge and experience of mine operators in this equipment. Their disadvantages of sub-optimal payload, poor operator ergonomics, inflexibility of operation and high operational costs are well known to mine operators. Despite this, they remain the dominant coal haulage vehicle used.

Mobile boot end

Mobile boot ends, similar to that shown in Fig. 6, have had limited penetration into the coal industry since their Australian introduction.

The mobile boot end is positioned behind the continuous miner and receives coal directly from the miner discharge boom. The mobile boot end then transfers coal production to the panel conveyor, which runs through the mobile boot end. The mobile boot end, which is self-propelled, moves forward following the continuous miner, and conveyor structure is added to extend the permanent belt whenever necessary.

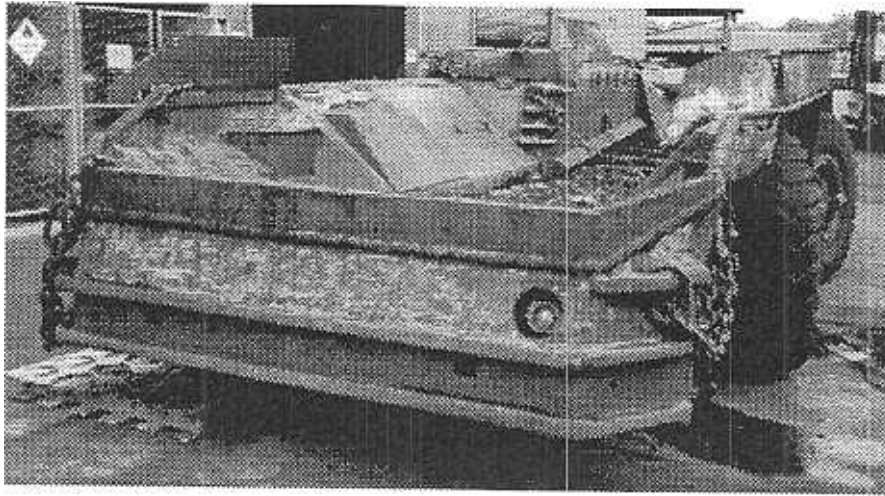


Fig. 5 - 15SC Shuttle Car

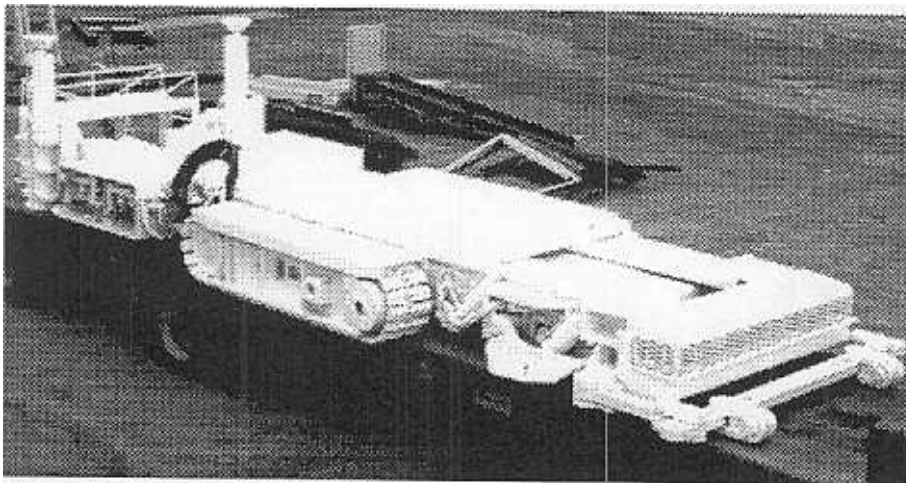


Fig. 6 - Mobile Boot End

The use of the mobile boot end is designed to be a continuous process. In practice, safety factors have limited the access of the mobile boot end to being a continuous process. Most mobile boot ends still in the field are currently being used as stationary boot ends.

The advantages of a mobile boot end primarily stem from its ability to provide a high capacity continuous coal clearance system.

The disadvantage of the mobile boot end generally lies in two areas.

1. Discipline is needed in operation of the unit to prevent panel conveyor problems and therefore prevent resultant loss of conveyor availability.

2. The severely constrained ability to re-supply the continuous miner with required materials for roof support and maintenance. Operators have designed narrow access supply vehicles and/or provided the ability to reverse the direction of the belt. The limited ability to re-supply the continuous miner can inhibit and to some extent, negate the advantage of its continuous coal clearance ability.

Battery haulers

Battery haulers, as shown in Fig. 7, whilst relatively new to Australia, have been extensively used in the US coal industry since 1984.

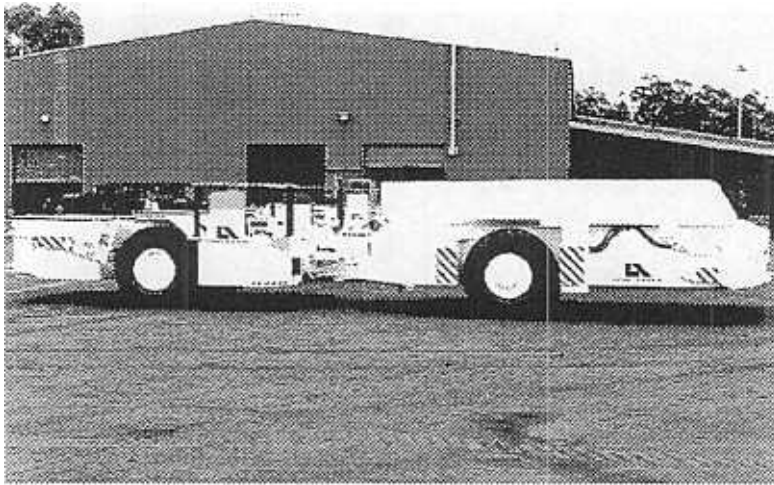


Fig. 7- CHA818 Un-a-Hauler

The advantages of battery coal haulers stem from a number of factors-

1. They have superior payload (11 tonnes to 18 tonnes).
2. They are not constrained in route and/or distance by trailing cables.
3. They have improved operator ergonomics (as compared to shuttle cars).
4. They have proven to be reliable.

The have utility use outside coal haulage.

There are four major disadvantages of battery coal haulers.

1. They are limited in continuous operation due to their stored energy source (batteries).
2. Their application is limited by the severity of roadway gradients.
3. They require underground charging facilities to operate in distant locations distant from the surface.
4. They require a disciplined battery management to ensure optimal performance.

Continuous haulage

A typical bridge type continuous haulage system is shown in Fig. 8.

The system extends and retracts by tramming along side the belt conveyor installation and transported coal is transferred to the panel conveyor via the RFM tailpiece. The tailpiece is capable of taking retraction of the entire length of the system plus the continuous miner.

Only one of this type of continuous haulage is in operation in the Australian coal industry, and it is currently being used in a place-changing multi-heading bord and pillar production panel.

Its use in gate road development is contemplated.

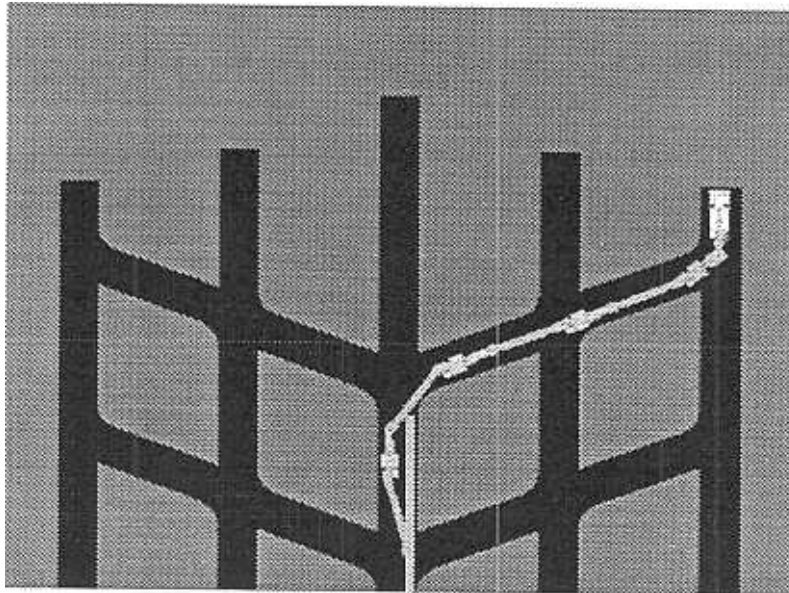


Fig. 8 - Continuous Haulage Unit

The advantages of this type of continuous haulage are seen as it

1. being capable of high haulage rates 600 TPH to 1800 TPH.
2. being able to be integrated into place-changing systems.
3. eliminating downtime caused through changing out battery haulers and/or shuttle cars.

The disadvantages of this system are seen as:-

1. the high capital cost of the system,
2. the system is best suited to angled cut throughs,
3. the belt conveyor road needs to be sufficiently wide to accommodate the panel conveyor and the bridge conveyor sections (normally 6.0m width required),
4. floor conditions in the conveyor roadway are critical to the success of the system,

5. re-supply of the continuous miner is impeded by bridge conveyor for the integrated mining and roadway support system of mining, and
6. a disciplined management of the operation of the system is essential to ensure its success.

COMPARISON OF RELATIVE EFFICIENCIES MINING SYSTEMS AND EQUIPMENT

The successful mine model

Table 1 is a requisite model indicating ultimate development needs to service a "typical state of the art" longwall mine. The mine has to achieve economic key performance indicators of 3.0 million ROM TPA and output per man year of at least 15,000 ROM tonnes.

Table 1 - Requirements for the typical 'State of the Art' modern longwall mine

DEVELOPMENT MODEL REQUIREMENTS FOR THE TYPICAL "STATE OF ART" MODERN LONGWALL MINE	
ECONOMIC KEY PERFORMANCE INDICATORS	
Annualised Production Output per Man Year	3.0 Million ROM Tonnes } eg. South Bulga design 15,000 ROM Tonnes } parameters
SETTING MINE PRODUCTION PARAMETERS	
Annual ROM tonnes divided by output per man year = Workforce Size Workforce Size Limits Mine To:-	3,000,000 Divided by 15,000 - 200 persons 1 x longwall unit plus 2 x development units
CALCULATING DEVELOPMENT REQUIREMENTS	
Parameters Tonnes per meter of development Tonnes per 1 meter longwall shear 2 x heading gate roads pillar dimensions	21.18 817.7 100m x 30m
Calculations 1 x metre of gate road panel advance = $(100+100+25)/100$ Therefore the ratio of development tonnes to longwall tonnes is: Gate road development tonnes @ 3,000,000 tpa & ratio 1:17.6 is: Add is a further 3280m for main road development: Calculate new development ratio: 3,000,000 divided by 11,534 x 21.18 Calculate annual production weeks as: Calculate required weekly production as: Calculate weekly development tonnes as 71,429 divided by 12.28 Calculate the number development unit shifts per week (p/w) as: Calculate the required metres per shift as:	2.25m face advance $817.7 \text{ divided by } 2.25 \times 21.18 = 1 \text{ to } 17.6$ $174,819 \text{ tonnes} = 8254\text{m (at 21.18 tonnes per metre)}$ $8254 + 3280 = 11,534 \text{ total development metres}$ 1 to 12.28 $52 - 2 \text{ (for P/H)} - 8 \text{ (2 x LW moves)} = 42 \text{ weeks}$ $3,000,000 \text{ divided by } 42 = 71,429 \text{ tonnes}$ $5817 \text{ tonnes} = 275\text{m}$ $(2\text{units} \times 5\text{days} \times 3\text{shifts}) - 2\text{shifts maintenance} = 28 \text{ production shift}$ $275 \text{ divided by } 28 = 9.82\text{m}$ $(100+100+25) \text{ divided by } 9.82 = 22.92 \text{ shifts}$

<p>Calculate the time required to complete each pillar as: Calculate the number of weeks to complete pillar @ 14 shifts p/w as: Add effect of each pillar service extension @ 6 x shifts or 0.4 weeks as: Calculate service extension compensated required development metres/shift:</p> <p>Calculate Effect of Development System Utilisation</p> <p>The above calculation assumes that the development system is 100% available Calculate availability adjusted development requirement using 70% availability.</p>	<p>22.92 divided by 14 = 1.64 weeks 1.64 weeks + 0.40 weeks = 2.04 weeks 2.04 weeks x 9.82 divided by 1.64 = 12.22m per shift</p> <p>Industry average availability lies between 60% and 75% 12.22 divided by 0.7 = 17.45m per shift.</p>
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NOTES

The above development model indicates the required shift development rates to support longwall production and achieve a combined development plus longwall annualised production of 3.0 million tonnes ROM.

Both development units would be required to achieve 17.45m per shift each for 14 shifts per week for at least 42 weeks per annum.

The model requires that two development units achieve at least 17.45 metres per shift for 14 shifts per week and for at least 42 weeks per annum. Only a minority of Australian longwall mines have achieved this level of development. The majority of Australian longwall mines would attain average development rates considerably less than this benchmark.

Opportunities for improvement

The author suggests that a choice of the most appropriate development system together with a system-matched suite of development equipment will provide the needed quantum improvement. To this end, some comparisons are presented to indicate options and their relative efficiencies.

A direct comparison between shuttle cars and battery haulers is shown for both the place-changing system (10 metre cut) and the integrated mining and roadway support system in Figs. 9 and 10 respectively.

In the modelled place-changing gate road development system, battery haulers offer efficiency improvements over shuttle cars ranging from 14% down to 4%. Battery haulers also provide opportunities to achieve acceptable development rates in pillar sizes exceeding 150 metres which is not achievable using shuttle cars.

In the more conventional integrated mining and roadway support system for gate road development battery haulers offer efficiency improvements over shuttle cars averaging 16% to 17%. Battery haulers also provide the opportunity again, to achieve acceptable development rates in pillar sizes exceeding 150m, which is not achievable using shuttle cars.

The model demonstrates that battery haulers provide the opportunity to extend pillar length to 250 metres without efficiency penalty, compared to shuttle cars hauling coal from the driveway of 60m and 100m pillars.

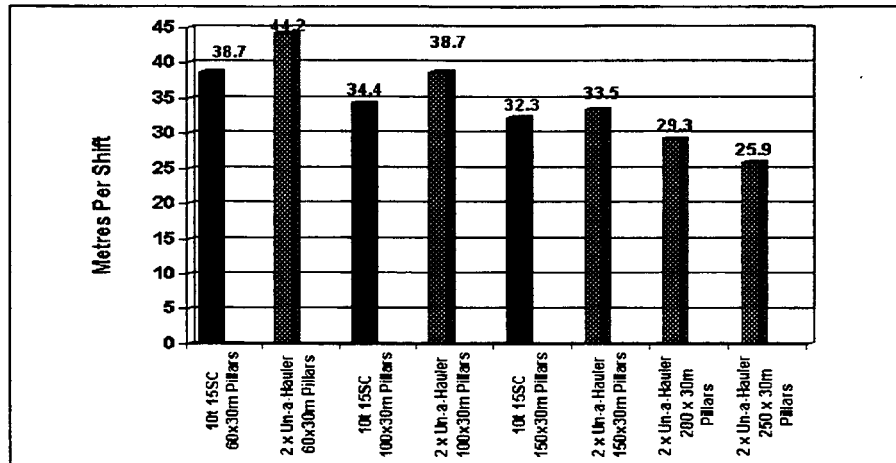


Fig. 9 - Shuttle cars vs Un-a-Haulers place changing development

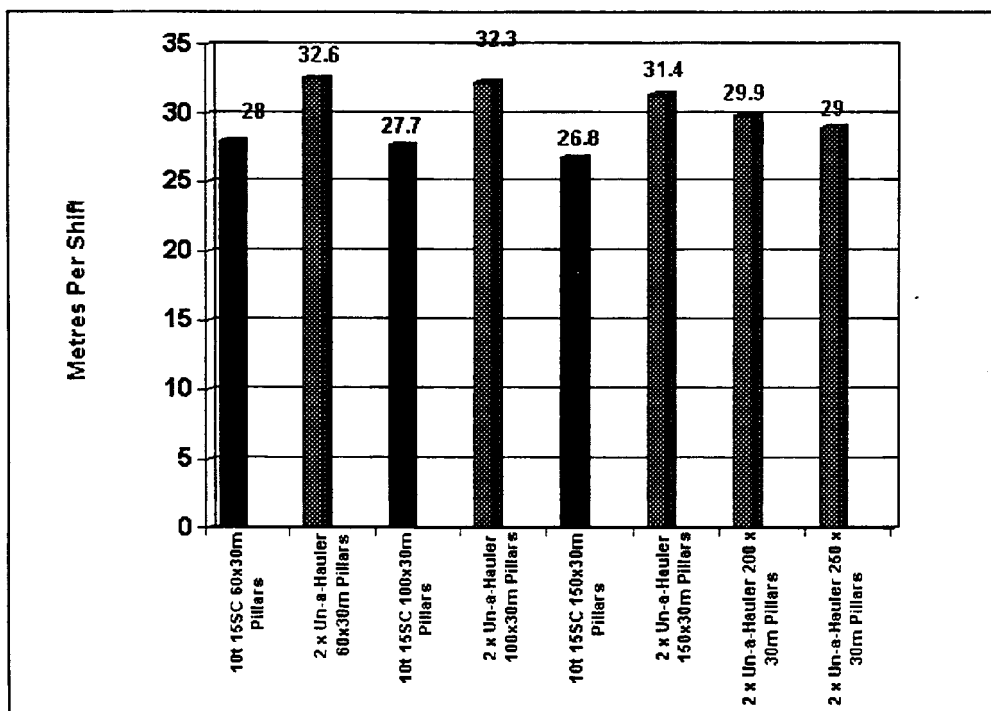


Fig. 10 - Shuttle Cars vs Un-a-Haulers Integrated mining and roadway support system (Conventional)

Continuous haulage

Modeling of continuous haulage for two heading gate development has been restricted to pillar lengths not exceeding 60m. The reason for this restriction is to keep the total length of the continuous haulage system to no greater than 100m, to enable reasonable management of the system in the confines of a two heading layout.

It is noteworthy to examine the modelled results from the introduction of continuous haulage as shown in the table below:-

Table 2 - Continuous Haulage projected efficiency improvements over shuttle cars

Pillar Dimensions	Place-Changing		Conventional	
	6m cut	10m cut	2.2m cut	3.0m cut
60m x 40m	69%	---	60%	---
60m x 30m	---	80%	---	61%

The indicative comparison of possible annualised savings through the replacement of shuttle cars by battery haulers in a particular mine application. The comparison is shown in Fig. 11.

The particular mine drives 2 x gate roads using a Voest Alpine ABM20 and shuttle cars.

Mobile boot end

In relation to the mobile boot end, the author has experience in the use of this equipment in single entry development.

Gate road entry development rates superior to that achievable by shuttle cars were experienced. However, regular shift development rates exceeding 6m caused continuous miner re-supply problems, which often impeded the use of the system.

Mobile boot end technology can provide improved results, particularly in single entry work, providing some compatible re-supply system is developed and integrated into the total mining system.

CONCLUSION

It is believed that coalmine operators have the opportunity to further consolidate improvements in gate road development rates.

Whilst significant technology advances have been made in integrated continuous miners, little attention has yet been given to improving coal clearance from the continuous miner.

Battery haulers provided efficiency gains across a spread of pillar sizes ranging from 110m x 40m to 250m x 40m. In an annualised meterage requirement for that development unit of 5,000 metres, efficiency gains converted to savings ranging from \$0.76 million pa to \$1.95 million.

This paper alludes to the opportunity for mine operators to improve development rates through the introduction of better-matched development systems and more efficient coal clearance systems currently procurable.

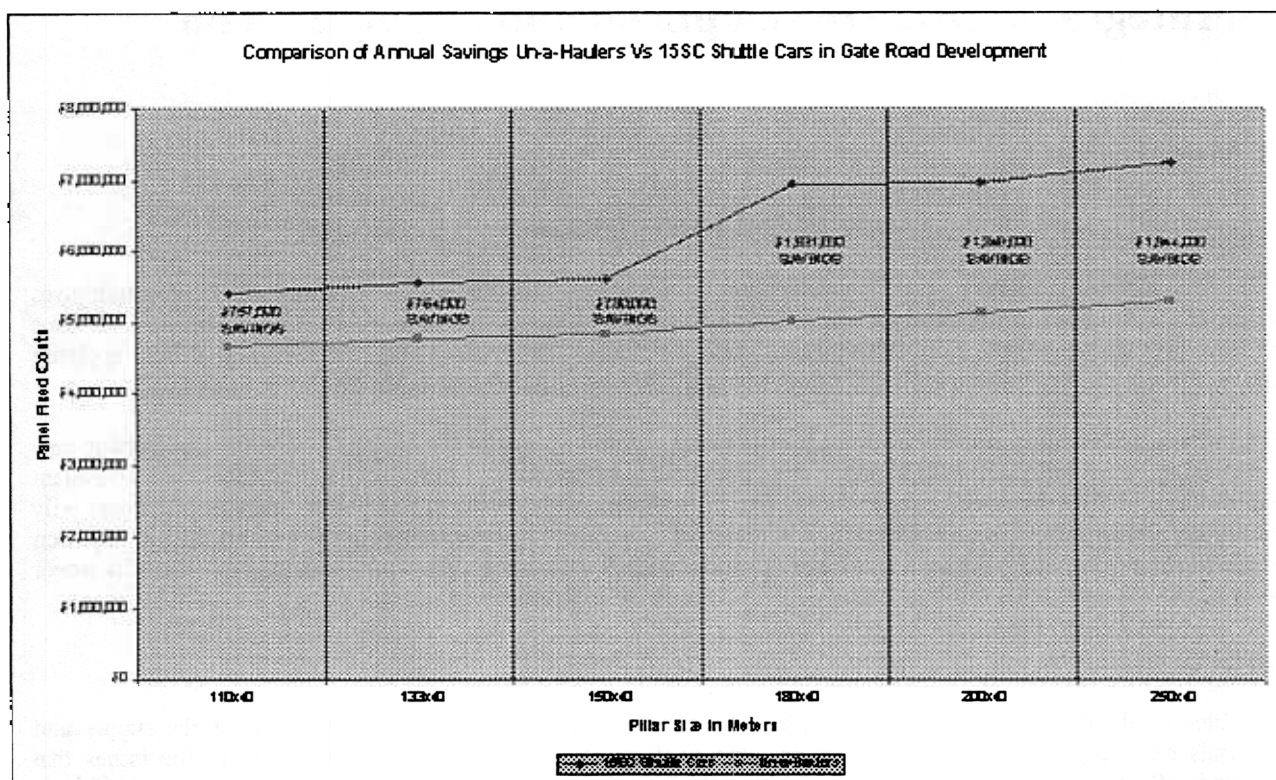


Fig. 11 - Comparison of annual savings Un-a-Haulers vs Shuttle cars in gateroad development